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CHANCE FOR SUCCESSIVE DRY YEARS IN SOUTHERN CALIFORNIA

A K SHOWALTER

[Weather Bureau Airport Station, Los Angeles, Calif.]

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This investigation of the possibilities for rainfall in the city of Los Angeles and in Southern California was undertaken in response to the ever-present public demand for knowledge of the future and in an attempt to answer some of the more particular questions raised following the dry winter of 1947-48.

From the preliminary survey of rainfall records for the seasons¹ of 1877-78 through 1946-47 for Southern California, it was determined that the Los Angeles record is representative of the characteristics of Southern California rainfall. Comparisons of the magnitude of seasonal rainfall recorded at the Weather Bureau City Office in Los Angeles with county-wide averages for Los Angeles County (Table 1) showed a correlation coefficient of 0.96. Similarly, a correlation coefficient of 0.80 between Los Angeles and San Diego rainfall (Table 2), although lower, served to support this conclusion.

In order to have a basis for comparing successive seasons it was necessary first to make some classification of them based on the monthly distribution and amounts of rainfall. One such classification made by Donnelly [1] defined six types of rainfall seasons. However, since the skewed frequency distribution characteristic of Southern California rainfall shows more years with below-average rainfall in Los Angeles than with above-average amounts (Table 3), other investigators have found that the division of the monthly and seasonal totals into three equal-frequency categories of light, moderate, and heavy is better adapted to their purposes. In the present study the equal-frequency divisions were used (based on figures in Table 4), with a change in terms to dry, normal, and wet, which seem to be better adapted to popular discussion. Strictly speaking, the middle category is no more normal than either of the others since it occurs with equal frequency. It might, in fact, be better to classify the upper quartile as wet years and the lower quartile as dry years, so as to give an equal number of normal and abnormal years, but the spread encompassed by normal years would be rather large.

With the years and months classified on an equal-frequency basis, the next step was the comparison of the number of observed successive months or years of record classed in the same category with the number which could be expected to occur by chance (Tables 5 and 6). A similar technique has been applied to rainfall for the Hawaiian Islands (Table 7) by Solot [2], whose investiga-

tions were concurrent with but independent of this study. Solot found that in the Hawaiian Islands both dry years and wet years occurred in succession much more often than could be expected by chance. However, the normal years, or as he labeled them, years with moderate rainfall, occurred with a frequency almost identical to what could be expected by chance. Los Angeles rainfall records, both for the city and county (Table 6), showed fewer successive years in the same category than could be expected by chance.

After the probabilities on the equal-frequency scale had been examined, additional investigation was made of the probabilities of occurrence of seasonal rainfall above or below the arithmetic average for Los Angeles. It was found that 43 percent of the 70 seasons studied had above-average rainfall in Los Angeles and 57 percent had below-average amounts (Table 3). The chance expectancy of an above-average year is, therefore, 0.43, and the probability of N successive years of above-average rainfall is 0.43 to the N th power. To compare this chance expectancy with observed seasonal rainfall, Table 8 was tabulated, and it was again found that successive years of the same character have not occurred as frequently as could be expected by chance. Similar results showed up in tests of monthly rainfall. Therefore, it can be concluded that probabilities indicate that rainfall amounts for a coming year in Los Angeles will be considerably different than those of the past year. In support of this conclusion, it was calculated that for the 70 years of record under consideration a 60-percent score would have been made by forecasting that a below-average year would be followed by an above-average year, or that an above-average year would be followed by a below-average year.

As a final part of the study, monthly and annual rainfall records of other cities of the United States were examined and results were tabulated (Table 9) on the basis of the equal-frequency categories. These results may be compared with the conclusions drawn from study of the Los Angeles records. The observed succession of years in the same category for some of the cities—Sacramento, Louisville, Denver, and Salt Lake City—proved to be less frequent than could be expected by chance. However, records from other cities—San Diego, Albany, St. Louis, Washington, and New York—showed that some of the observed successions of years of the same category were repeated much more frequently than indicated by chance expectancy. This was particularly true of Albany, N. Y., although there is some evidence that the long record for this station is not necessarily homogeneous.

¹ The rainfall season, or rainfall year, in Southern California is usually accepted as July 1 to June 30. Although this definition was not strictly adhered to in all phases of this study, the period was selected in each case so that it includes a complete winter.

REFERENCES

1. Maurice Donnelly, "Monthly Rainfall Distribution in Southern California with Special Reference to Soil Erosion Problems," *Transactions, American Geophysical Union*, Part I, October 1943, pp. 144-148.

2. S. B. Solot, "Possibility of Long Range Precipitation Forecasting for the Hawaiian Islands," *Research Paper No. 28*, Weather Bureau, Washington, D. C., January 1948.

TABLE 1.—Contingency table showing correlation of seasonal rainfall in the city of Los Angeles with the county-wide average seasonal rainfall in Los Angeles County (68 seasons, October 1 to September 30)

		CITY OF LOS ANGELES			Total
		Dry	Normal	Wet	
LOS ANGELES COUNTY	Dry.....	20	4	0	24
	Normal.....	2	15	5	22
	Wet.....	0	4	18	22
Total.....		22	23	23	68

TABLE 2.—Contingency table showing correlation of seasonal rainfall in city of Los Angeles with that in San Diego (70 seasons, July 1 to June 30)

		LOS ANGELES			Total
		Dry	Normal	Wet	
SAN DIEGO	Dry.....	14	9	0	23
	Normal.....	8	9	8	25
	Wet.....	1	7	14	22
Total.....		23	25	22	70

TABLE 3.—Table showing percentage of occurrence by months of various precipitation classes (70 years, city of Los Angeles)

Month	Percentage of months			
	With trace or none	Above average	Over 1.00 inch	Over 3.00 inches
July.....	86	11	0	0
August.....	69	13	0	0
September.....	59	19	6	1
October.....	11	31	19	1
November.....	17	36	40	11
December.....	7	39	70	39
January.....	1	39	71	38
February.....	7	36	71	39
March.....	1	37	69	34
April.....	4	30	30	10
May.....	21	24	11	1
June.....	53	16	1	0
Season.....	43			

TABLE 4.—Rainfall amounts (inches) by months and season for city of Los Angeles for 70 years of record

Month	Wettest month	Equal-frequency limits		Median value	Arithmetic mean	Driest month
		Lower limit of wet month	Upper limit of dry month			
July.....	0.24	T+	0	T	0.01	0
August.....	.61	T+	0	T	.03	0
September.....	5.67	0.03+	0	T	.21	0
October.....	6.96	.60+	0.13-	0.27	.63	0
November.....	6.53	1.20+	.20-	.60	1.14	0
December.....	15.80	3.66+	1.02-	2.35	2.88	0
January.....	13.30	3.20+	1.15-	2.20	2.96	T
February.....	13.37	3.40+	1.25-	2.35	3.33	0
March.....	12.36	3.00+	1.30-	2.25	2.75	T
April.....	7.53	.84+	.25-	.46	1.03	T
May.....	3.67	.25+	.03-	.09	.38	0
June.....	1.39	.02+	T-	T	.07	0
Season.....	38.18	17.75	12.00-	13.66	15.40	5.59

TABLE 5.—Expected and observed occurrences of successive months with same rainfall class (70 seasons, November to April) for city of Los Angeles

Successive months	Probability	Number of opportunities	Expected occurrences	Observed occurrences		
				Wet	Normal	Dry
1.....	1/3	420	140	140	139	141
2.....	1/9	350	39	38	28	33
3.....	1/27	280	10	7	7	8
4.....	1/81	210	3	0	2	3
5.....	1/243	140	1	0	0	0
6.....	1/729	70	0	0	0	0

TABLE 6.—Expected and observed occurrences of successive years with same rainfall class

CITY OF LOS ANGELES (70 seasons)						
Successive years	Probability	Number of opportunities	Expected occurrences	Observed occurrences		
				Wet ¹	Normal	Dry ²
1.....	1/3	70	23	23	24	23
2.....	1/9	69	8	6	5	8
3.....	1/27	68	3	1	0	2
4.....	1/81	67	1	0	0	0

LOS ANGELES COUNTY
(75 seasons)

Successive years	Probability	Number of opportunities	Expected occurrences	Observed occurrences		
				Wet ¹	Normal	Dry ²
1.....	1/3	75	25	24	26	25
2.....	1/9	74	8	7	8	8
3.....	1/27	73	3	2	2	4
4.....	1/81	72	1	0	0	0

¹ Wet season, over 115 percent of the arithmetic average.

² Dry season, less than 79 percent of the arithmetic average.

TABLE 7.—Chance and observed recurrence intervals of successive months with same rainfall class for Hawaiian Islands (from Solot [2])

Successive months	Chance interval of recurrence	Observed interval of recurrence		
		Light	Moderate	Heavy
1.....	3	3	3	3
2.....	9	6	9	6
3.....	27	12	27	18
4.....	81	24	81	36
5.....	243	42	243	72
6.....	729	84		180
7.....	2,187	156		420
8.....	6,561	300		
9.....	19,683	588		

TABLE 8.—Expected and observed occurrences of successive years with rainfall above and below the arithmetic average (70 years) for city of Los Angeles

Successive years	Number of opportunities	Probability for above average	Above average		Probability for below average	Below average	
			Expected occurrences	Observed occurrences		Expected occurrences	Observed occurrences
1.....	70	0.43	30	30	0.57	40	40
2.....	69	(.43) ¹	13	9	(.57) ²	22	19
3.....	68	(.43) ¹	5	2	(.57) ²	13	9
4.....	67	(.43) ¹	2	0	(.57) ²	7	3
5.....	66	(.43) ¹	1	0	(.57) ²	4	1

TABLE 9.—*Expected and observed occurrences of successive years with same rainfall class*

SAN DIEGO, CALIF.

(97 years)

Successive years	Expected occurrences	Observed occurrences		
		Wet	Normal	Dry
1.....	32	31	34	32
2.....	11	10	11	11
3.....	4	5	3	7
4.....	1	3	2	3
5.....	0	1	0	1

ALBANY, N. Y.¹

(121 years)

1.....	40	40	41	40
2.....	14	17	15	19
3.....	5	11	6	13
4.....	2	6	1	9
5.....	1	1	0	7
6.....	0	0	0	6
7.....	0	0	0	5
8.....	0	0	0	4
9.....	0	0	0	3
10.....	0	0	0	2
11.....	0	0	0	1

SACRAMENTO, CALIF.

(97 years)

1.....	32	34	31	32
2.....	11	9	9	12
3.....	4	2	3	3
4.....	1	0	0	1

ST. LOUIS, MO.

(111 years)

1.....	37	37	37	37
2.....	12	14	11	13
3.....	4	6	1	2
4.....	1	4	0	0
5.....	0	3	0	0
6.....	0	2	0	0
7.....	0	1	0	0

¹ A preponderance of wet years before 1870 and of dry years after 1900 suggests the possibility of a discontinuity in the representativeness of the rain gage location at Albany.TABLE 9.—*Expected and observed occurrences of successive years with same rainfall class—Continued*

LOUISVILLE, KY.

(73 years)

Successive years	Expected occurrences	Observed occurrences		
		Wet	Normal	Dry
1.....	24	25	24	24
2.....	8	6	5	7
3.....	3	3	1	1
4.....	1	1	0	0

DENVER, COLO.

(76 years)

1.....	25	25	26	25
2.....	8	9	6	5
3.....	3	3	0	1
4.....	1	0	0	0

SALT LAKE CITY, UTAH

(73 years)

1.....	24	24	24	25
2.....	8	9	7	5
3.....	3	3	0	1
4.....	1	1	0	0

WASHINGTON, D. C.

(75 years)

1.....	25	25	25	25
2.....	8	11	12	7
3.....	3	6	3	2
4.....	1	2	1	1
5.....	0	1	0	0

NEW YORK CITY

(74 years)

1.....	25	25	24	25
2.....	8	11	10	10
3.....	3	5	7	4
4.....	1	2	4	1
5.....	0	1	2	0
6.....	0	0	1	0

